VI. *Additional Note to the Eleventh Series of Researches on the Tides. By the Rev.* W. Whewell, *B.D. F.R.S., Fellow of Trinity College, Cambridge.*

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THE tide observations which I recorded and discussed in my eleventh memoir on that subject, were laid before the Royal Society, because, though the different series of observations were both brief and imperfect, the features of the tide phenomena as there exhibited were novel; and it appeared desirable to put them on record with a view to future comparison with other places. I have now to notice other observations which I have received from another region, and which display similar features in a still more remarkable manner. These, with the results of a few other sets of observations, which may, I trust, hereafter be of use, I beg to lay before the Society, as an Appendix to my eleventh memoir on the subject of the Tides.

The principal tide observations which I now bring forward are those for which I am indebted to the Russian Admiral Lütke. These observations were made in 1827 and 1828 by the officers and men of the *Seniavine* corvette, commanded by the (then) Captain Lütke. From the account given me of the mode of observing, it appears that they were made with proper apparatus and with great care and perseverance, as is indeed sufficiently shown by the observations themselves. At one place (Petropaulofsk in Kamtchatka) the height of the surface was carefully observed every ten minutes day and night; and when near its maximum, every two minutes. And it is proper to remark, that this great care and labour, which would have been superfluous at most places, was necessary in this instance. If the observations had not been thus continued, they would not have enabled us to detect the very curious laws of the phenomena which I have now to describe.

I shall first state the peculiar features of the tide phenomena shown by these observations; and I shall afterwards add such portions of the registers and calculations as seem requisite to confirm and illustrate what I shall state.

1. *Petropaulofsk*, in the Bay of Avatcha, peninsula of Kamtchatka, latitude 53°·1 N., longitude 158° 44′ E. Observations made in October 1827, June 1838, October and November 1828.

On laying down these observations, in our usual manner, in curve lines, it appeared (as at Bassadore, already noticed in this memoir,) that the *high* water is affected in its *time* by a very large diurnal inequality, while the *height* is only slightly affected by an inequality of that kind. This diurnal inequality of the time reaches the enormous amount of above *four hours*; thus the intervals (between moon's transit and

high water) on October 11 and 12, 1827, were as follows: $5^h\ 38^m$, $1^h\ 39^m$, $5^h\ 20^m$, $0^h\ 56^m$; on June 23 and 24, 1828, they were $7^h\ 9^m$, $3^h\ 9^m$, $7^h\ 21^m$, $2^h\ 51^m$; on October 15 and 16, 1828, they were $5^h\ 13^m$, $2^h\ 0^m$, $6^h\ 7^m$, $2^h\ 46^m$; showing an alternate increase and diminution to the extent I have mentioned. The greatest alternate inequalities of the heights of high water during the series of observations which I have mentioned, were something more than a foot.

But when we examine the observations of *low* water, we find the case marked by additional features, which render it still more curious. For, in the low waters, the diurnal inequality of the times appears indeed, but is neither so large nor so regular as the inequality of the times of high water; it amounts at some periods to *one hour*, but not often to more. The diurnal inequality of the *height* of low water, on the other hand, is much larger than that for high water, reaching the amount of three, or even four feet; and this, in a tide of which the whole rise, from the lowest to the highest, rarely exceeds five feet.

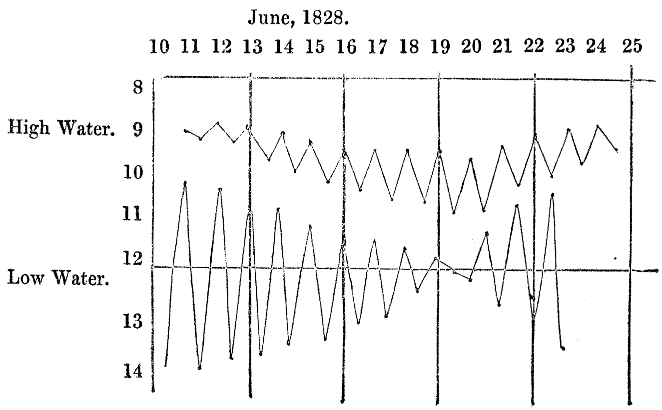
The diurnal inequality depends, as is well known, upon the moon's declination; and its maximum and its disappearance have been found, at most places hitherto examined, to follow at a short interval (one or two days) the maximum and the vanishing of the moon's declination. If we examine the Petropaulofsk observations with regard to this point, we find that the greatest and most regular of the diurnal inequalities which I have noticed, the inequality of the time of high water and of the height of low water, correspond with the moon's declination; they have their maximum when the declination is greatest, whether north or south, and pass from positive to negative on the very day on which the moon crosses the equator. Using the phrases which have previously been employed on this subject, the *epoch* of the diurnal inequality is zero, and the effect of the moon's declination reaches Petropaulofsk without any delay or retardation.

But this view of the laws of the tides at this place, which might otherwise be accepted without difficulty, is extremely perplexed and interfered with by the other parts of the diurnal inequality,—the inequality of heights at high water and of times of low water. For though these inequalities are not so large or so regular as the others, still they are sufficiently marked and steady to allow their laws to be seen beyond doubt. And it appears, not only that the epoch of these parts of the inequality does not agree with that of the others, but that these two inequalities *alternate* with the other two, vanishing when the other reach their maxima, and showing their maxima when the others vanish.

This is a very perplexing circumstance; for we cannot doubt that the diurnal inequality depends upon the moon's not moving in the equator; and therefore, how this inequality should affect the height of high water and the time of low water most, at that period at which the moon is in the equator, it is difficult to conceive. As the series of observations upon which my inferences are founded are but short (three series of a few weeks each), it might be doubted perhaps whether they are sufficient

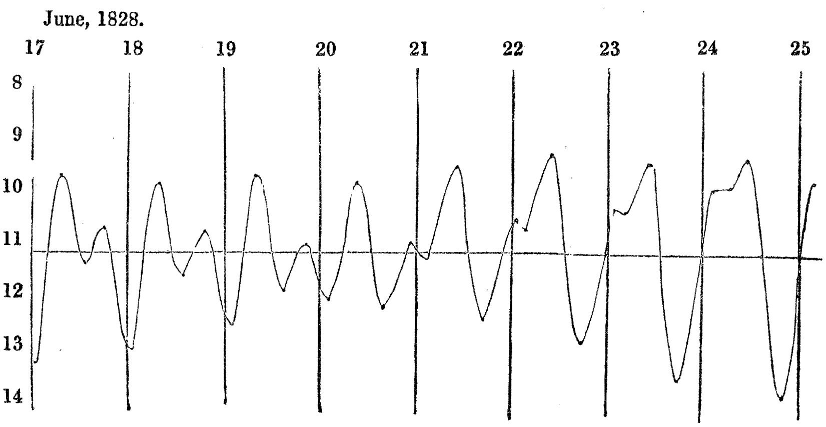
to establish so curious a rule as this. I think no one looking at the observations thrown into the form of curves, will doubt that in them a rule of this kind really prevails; but I quite agree with the opinion, that in order to fix the rule with exactness a larger series of careful observations is requisite. In order that the reader may judge for himself, I annex the figures given by the observations for June 1828.

Petropaulofsk Heights.



I shall proceed to point out a few additional inferences which offer themselves as resulting from the Petropaulofsk tidal phenomena, before I proceed to the observations made at other places.

Single-Day Tides.—The tides of Petropaulofsk show more clearly than any that have yet been examined, the manner in which the diurnal inequality may be so large as to lead to the appearance of only one tide in the twenty-four (lunar) hours. This will be very readily seen, if we follow the motion of the surface of the water for a few days, which is done in the accompanying figure.



The vertical lines in this figure represent the heights of the surface, and the horizontal space measures the time, each division being a day. It will be seen that there are on each day two high waters, excepting the 21st, when the second high water passes over to the 22nd, in consequence of the lunar being larger than the solar day. The heights of the high waters are alternately greater and less; as are also, in a still

greater degree, the heights of the low waters. And thus some of the high waters are depressed, and some of the low waters elevated, till there is little vertical distance between the two. On the 17th of June the rise from low to high water in the afternoon was only eight inches, although the rise in the forenoon had been four feet. In the same manner, the fall from high to low water in the forenoon of June 22 was only two inches, and in the forenoon of June 23 only one inch, although the intermediate fall in the afternoon of those days was above four feet. And these movements of the surface in the forenoons of those days, which we have called a fall from high to low water, are in fact more simply conceived as a mere temporary check in the rise of the water from the preceding low to the succeeding high water. And accordingly on June 24 the movement plainly assumes this character; the ascent is checked, but no descent takes place. In the register of the observations it is stated that "from 6^h to 8^h the surface remained stationary, so that we may say there was no low water." And thus one of the two half-daily tides being obliterated, we have at this period only one tide in the twenty-four hours.

This phenomenon, or an approximation to it, has already come under our notice in the tides of Sincapore, of the Keeling Islands, and of Bassadore; and has been noticed by others in other places. It is to be recollected, however, that this reduction of the two half-day tides to a single-day tide takes place only at a particular period of each lunation, depending upon the declination of the moon. When therefore a traveller has such a phenomenon brought under his notice, he should recollect that by pursuing his tide observations for a few days with assiduity, he will find the single-day tide resolve itself into the usual case of two daily tides.

"The establishment" ceases to be applicable.—The diurnal inequality affects the time of high water at Petropaulofsk to a very large amount, as we have seen; and hence the interval of moon's transit and high water, whether taken at the syzygy or at any other time, may vary very much from one tide to another. I have already noticed cases in which these intervals were alternately 1^h and 5^h, 2^h and 6^h, 3^h and 7^h. Now this being the case, what do we mean by the Establishment of the place? Supposing such observations as those just mentioned to be made at the syzygy, which of the two numbers of hours is to be taken as the *establishment*, in the common sense of the term? There is no ground for preferring either to the other, and therefore we cannot with any propriety deduce the establishment from either.

Perhaps it will be said that we may take the mean of two, or of an even number of successive high waters; and thus obtain an approximation to the establishment, such as it would be if not affected by the diurnal inequality. But even if a mean establishment were so obtained, it could not be applied. Thus if it appeared that the lunitidal interval for the time of syzygy, cleared of diurnal inequality, were five hours, still, as the cycle of the diurnal inequality is entirely different from the time between syzygy and syzygy, the interval at syzygy may not be affected at all by the inequality, or it may be affected by the greatest positive, or by the greatest negative value. It

may thus be five hours, or seven hours, or three hours. And this uncertainty deprives the establishment of all utility in such cases as the one before us, except we also take into account the diurnal inequality.

If, after laying down the lunitidal intervals as ordinates, we draw a line cutting off the diurnal inequality, according to the method which we have previously employed, we find that the semimenstrual line gives intervals oscillating between the (mean) values of $3^h\ 39^m$ and $5^h\ 25^m$. Hence the mean lunitidal interval or *corrected* establishment (using terms explained in former memoirs) is $4^h\ 32^m$: and the maximum amount of the semimenstrual inequality (positive and negative) is 53^m, and its total variation during a semilunation is 106^m; which is larger than the variation at most places. Hence we see of what very wide changes the lunitidal interval at Petropaulofsk is susceptible. If we take the maximum of the diurnal inequality (positive or negative) at two hours, the lunitidal interval may vary from $1^h\ 39^m$ to $7^h\ 25^m$; and thus the constancy of the establishment is quite obliterated. And even in this statement, we have not taken account of the effects of the parallax of the moon, and the effect of her declination upon the diurnal mean.

Diurnal Tide Wave.—As I have shown in former memoirs, we may represent the usual diurnal inequality at any place as the effect of a tide wave arriving at the shore once a day and superimposed upon the semidiurnal tide wave. We are naturally led to ask whether such a mode of representation is applicable to the tides now under consideration. The features which the diurnal inequality exhibits at Petropaulofsk are not, for the most part, inconsistent with such a representation. Thus, that the inequality should affect high water and low water very differently, is easily explained. Nor is there any difficulty in accommodating the hypothesis of the diurnal wave to one of the most curious of the laws which we have discovered; namely to this, that the inequality affects in the largest degree the *time* of high water and the *height* of low water. It is perhaps worth while to show this. In order to simplify the case as much as possible, I shall state and prove the following proposition.

If the maximum of the diurnal wave coincides with the minimum of the semidiurnal wave, there will be a diurnal inequality of the *time* of high water, and of the *height* of low water, depending upon the proportion of the maxima of the two waves; but there will be no diurnal inequality in the *height* of high water or in the *time* of low water.

Let t be any time measured in (lunar) half-days from a given high water; then the height (above mean water) of a semidiurnal tide may be represented (omitting inequalities) by $a \cos 2\pi t$. This gives high water when t is 0, 1, 2, or any whole number, and low water when t is $\frac{1}{2}$, $\frac{3}{2}$, or the half of any odd number. On the same supposition a diurnal tide might be represented by $b \cos \pi t$, which is a maximum when t is 0, 2, 4, and a minimum when t is 1, 3, 5, &c. But since the maximum of the semidiurnal and of the diurnal tide do not necessarily coincide, the latter may be represented

more generally by $b \cos (\pi t - \beta)$, which, when β is a quadrant, becomes $b \sin \pi t$. In this case the maximum of the diurnal wave coincides with the minimum of the semidiurnal: and the compound wave is $a \cos 2 \pi t + b \sin \pi t$.

In this case it is proposed to find the diurnal inequality. For high and low water we have, by the rule for maxima,

$$-2 a \sin 2 \pi t + b \cos \pi t = 0, \text{ or } b \cos \pi t = 4 a \sin \pi t \,.\, \cos \pi t.$$

Hence

$$\cos \pi t = 0, \text{ or } \sin \pi t = \frac{b}{4a}.$$

The former value gives for t the values $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, &c., which belong to the time of low water, and show that the time of low water is not altered by the diurnal wave.

The other value gives for t a certain fraction x, and also the numbers $1 - x$, $2 + x$, $3 - x$, &c.; these belong to the time of high water, and show that the time of high water is affected by a diurnal inequality, of which the maximum, positive and negative, is x.

The height of low water is obtained by substituting, for t, the values $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, &c. which give the *depressions*, $a - b$, $a + b$, $a - b$, &c., showing that the height of low water is affected by a semidiurnal inequality, of which the maximum is b positive and negative. The height of high water is obtained by substituting, for t, x, $1 - x$, $2 + x$, $3 - x$, all which give the values $a \cos 2 \pi x + b \sin \pi x$, or $a + \frac{b^2}{8a}$; showing that there is no diurnal inequality of height in the high water.

If the maximum of the diurnal wave do not coincide either with the maximum or the minimum of the semidiurnal, the compound wave will be $a \cos 2 \pi t + b \cos (\pi t - \beta)$; and there will be inequalities both of time and of height, both for high and low water. And the inequalities at high and low water will bear certain proportions depending upon β and $\frac{b}{a}$; and conversely, if the proportions of the high-water and low-water diurnal inequalities of time and height be known, the quantities β and $\frac{b}{a}$ may be found.

But all this is applicable so long only as the inequalities of high and of low water coincide in their cycles, reaching their maxima and vanishing together; and as we have seen that, instead of doing this, they reach their maxima and vanish alternately, we are compelled to give up (in this instance) this mode of representing the diurnal inequality by means of a diurnal wave.

Under the present aspect of the subject, I do not conceive that we can pursue this examination further with advantage, till we possess a longer series of careful observations of the Petropaulofsk tides. The singular laws which the tides there follow makes it a matter of interest to science to have these laws still further established

and analysed; the knowledge that the case does thus deserve further inquiry, we owe to the very great exactness and perseverance with which the observations were made by Admiral LÜTKE in 1827 and 1828.

2. Port of *Novo-Arkhangelsk*, Isle of *Sitkhœ*, Norfolk Sound, on the north-west coast of America, latitude 57° 2′ N., longitude 135° 18′ west of Greenwich. Observations made in July 1827*.

The Isle of Sitkhœ is nearly in the same latitude as Kamtchatka, on the opposite side of the Northern Pacific, the distance of the two coasts being in that part about 66 degrees of longitude. The differences which have been found to prevail in the phenomena of the tides even in places almost adjacent, leave us without any good ground of expectation that the tides of these two coasts will be found to resemble each other, even in their general features. It is found, however, that some of the most curious of the circumstances which mark the Petropaulofsk tides, appear also in those of Novo-Arkhangelsk.

The Sitkhœ tides exhibit a very great diurnal inequality both in the heights and in the times. The amount of this inequality at high water reaches an hour (half an hour positive and negative); at low water it is somewhat less. The diurnal inequality of the height of high water is two feet and a half; at low water its maximum effect amounted to five feet, the greatest rise from low water to high water being about fifteen feet.

Thus we see that at Sitkhœ, as in Kamtchatka, there is a very large diurnal inequality which affects the time of high water more, and the height less, than those of low water. The motion of the surface will be in its general features the same in this as in the former case, although it does not appear, so far as the observations before us can show, that one of the two semidiurnal tides is ever obliterated.

I may add, that it appears also, so far as we can judge from a short series of observations, (a month, with interruptions,) that the maximum and zero of the high-water diurnal inequalities alternate with those of low water, which we have already noticed as so perplexing a circumstance at Petropaulofsk.

The diurnal inequality being allowed for, we obtain a semimenstrual inequality of the mean tide at Sitkhœ, which is tolerably regular. According to our discussion, the greatest and least lunitidal intervals are $12^h\ 10^m$, and $13^h\ 25^m$ from the lunar transit of the preceding half-day; the mean on the corrected establishment being $12^h\ 49^m$, and the total amount of the semimenstrual inequality 75^m.

Under these circumstances we cannot doubt that the tides of Kamtchatka and Sitkhœ are to be explained in the same way, whatever the explanation may be; and probably the same features extend in some measure over the whole of the North Pacific.

* Some additional observations were made in 1832 and 1833, but too interruptedly to be of much service in these discussions.

3. *Port de la Coquille*, Isle of Ualan, Caroline Archipelago, latitude 5° 21′ N., longitude 163° 5′ east of Greenwich. Observations made in December 1827.

These observations were made for about nineteen days, with interruptions. They exhibit some of the same features as the two preceding places; a very large diurnal inequality, both of the heights and times, and both at high and low water. In this case the inequality of the heights appears to be greatest for high water. Also its maximum appears to alternate with the maximum of the inequality for low water; but the series of observations is too short and incomplete to determine this point with certainty.

Having allowed for the diurnal inequality, we obtain a very large semimenstrual inequality. The lunitidal intervals appear to oscillate from $3^h\ 30^m$ to $6^h\ 16^m$. These very wide changes may throw suspicion upon the exactness of the observations; yet the changes are so regular and continuous, as greatly to remove such suspicions. According to these results the mean lunitidal interval or corrected establishment is $4^h\ 53^m$.

4. *Port Lloyd*, Isle *Bonine-Sima*, latitude 27° 5′ N., longitude 142° 5′ west of Greenwich. Observations made May 1828.

Port Lloyd has a very large diurnal inequality, affecting both the times and the heights; it affects most the high-water times and the low-water heights. In the inequality of the heights, the maxima for high water and low water appear to alternate; in the times, this is more obscure; but we cannot expect clear evidence on this head, the observations including only nine days.

For the same reason it is impossible to state with any precision the establishment of this place. The maximum lunitidal interval (cleared of diurnal inequality) is $8^h\ 42^m$; and from the course of the curve which represents the observations, it appears certain that the semimenstrual inequality of times is large. If this inequality be two hours, the mean lunitidal interval will be $7^h\ 42^m$.

The observations sent by Admiral LÜTKE contained an account of the Establishment of several other places in the North Pacific; but, as I have already stated, the term *establishment* becomes in the highest degree vague, and almost unmeaning, when applied to seas in which the phenomena of the tides are such as are described in the present paper.

P.S. From the account of Admiral FREYCINET's voyage, it appears that at several places in the North Pacific, the tides, as observed in that expedition, exhibit features similar to those here noticed.

Petropaulofsk.

	Moon's Transit.	High Water.		Interval.	Low Water.		Interval.
		Times.	Heights.		Times.	Heights.	
1827.	h m	h m	ft. in.	h m	h m	ft. in.	h m
Oct. 1 A.M.	7 57	1 50	16 10	5 53	6 43	18 1	10 46
P.M.	8 24	52	16 11	4 28	7 20	19 7	10 56
2 A.M.	8 50	2 8	16 8	5 18	8 13	18 9	11 23
P.M.	9 16	2 24	16 8	5 8	8 21	19 0	11 5
3 A.M.	9 42	2 48	16 3	5 6	9 5	19 0	11 23
P.M.	10 7	3 24	16 1	5 17	9 42	18 6	11 35
4 A.M.	10 31	3 32	16 1	5 1	10 15	19 9	11 44
P.M.	10 56	4 44	16 10	5 48	10 8	18 3	11 12
5 A.M.	11 20	3 50	16 0	4 30	10 42	20 1	11 22
P.M.	11 44	5 20	16 2	5 36	10 44	18 4	11 0
6 A.M.	8	4 32	16 3	4 24	11 1	20 5	10 53
P.M.	32	6 3	16 0	5 31			
7 A.M.	56	5 10	16 0	4 14	3	17 11	11 31
P.M.	1 20	7 11	16 1	5 51	22	20 6	11 26
8 A.M.	1 45	5 26	16 1	3 41	11 40	17 8	10 20
P.M.	2 10	7 54	16 3	5 44	45	20 4	11 0
9 A.M.	2 34	5 51	16 2	3 17	17	17 4	10 7
P.M.	2 57	8 18	16 2	5 21	1 5	20 3	10 31
10 A.M.	3 21	6 19	16 3	2 58	1 30	17 2	10 33
P.M.	3 45	8 51	16 6	5 6			
11 A.M.	4 10	7 6	16 9	2 56	2 6	17 6	10 21
P.M.	4 34	10 12	17 0	5 38	2 30	20 2	10 20
12 A.M.	4 58	6 37	17 0	1 39	3 7	17 7	10 33
P.M.	5 22	10 42	16 3	5 20	3 7	19 9	10 9
13 A.M.	5 46	6 42	16 7	56	3 54	17 0	10 32
P.M.	....	....	....	....	4 59	19 6	11 13
14 A.M.	6 9	12	16 11	6 3	5 20	17 7	11 11
P.M.	6 31	10 42	17 3	4 11	4 35	18 11	10 4
15 A.M.	6 54	1 9	16 8	6 15	7 11	18 0	12 21
P.M.	7 17	11 59	17 4	4 42	6 49	19 3	11 32
16 A.M.	7 39	1 15	17 2	5 36	7 26	18 10	11 47
P.M.	8 2	2 7	17 7	6 5	7 46	19 0	11 44
17 A.M.	8 25	1 38	17 0	5 15	7 52	18 11	11 27
P.M.	8 49	2 44	17 0	5 55	8 28	18 7	11 39
18 A.M.	9 12	2 25	16 9	5 13	8 59	19 9	11 47
P.M.	9 35	3 22	17 0	5 47	9 7	18 5	11 32
19 A.M.	9 59	2 27	16 9	4 28	9 50	20 3	11 51
P.M.	10 23	4 39	16 6	6 16	10 2	17 11	11 39
20 A.M.	10 48	2 56	16 4	4 8	10 17	20 7	11 29
P.M.	11 14	5 38	16 0	6 24	10 39	17 5	11 25
21 A.M.	11 40	3 27	16 1	3 47	10 43	20 9	11 3
P.M.	6	6 28	15 9	6 22	11 15	17 0	11 9
22 A.M.	34	3 58	15 8	3 24	11 23	20 10	10 49
P.M.	1 2	6 53	15 1	5 51			
23 A.M.	1 31	4 41	15 10	3 10	6	17 2	11 4
P.M.	2 1	7 44	16 3	5 43	44	21 2	11 13
24 A.M.	2 30	4 59	16 1	2 29	26	17 2	10 25
P.M.	2 59	8 36	16 5	5 37	51	21 3	10 21
25 A.M.	3 28	5 45	16 2	2 17	1 30	17 2	10 31
P.M.	3 58	9 38	16 2	5 40	2 7	20 10	10 39
26 A.M.	....	....	....	....	2 53	17 0	10 55
1828.							
June 10 A.M.							
P.M.	10 2	....	....	....	9 21	14 1	11 19
11 A.M.	10 26	4 46	9 1	6 20	9 48	10 1	11 22
P.M.	10 51	2 34	9 3	3 43	10 15	14 1	11 24

Petropaulofsk. (Continued.)

	Moon's Transit.	High Water.		Interval.	Low Water.		Interval.
		Times.	Heights.		Times.	Heights.	
1828.	h m	h m	ft. in.	h m	h m	ft. in.	h m
June 12 A.M.	11 16	5 30	8 11	6 14	10 58	10 1	11 42
P.M.	11 41	2 37	9 4	2 56	10 48	14 2	11 7
13 A.M.	6	5 56	9 0	5 50	11 55	10 4	11 49
P.M.	30	3 11	9 8	2 41	11 18	14 2	10 48
14 A.M.	55	6 41	9 2	5 46	36	10 7	11 41
P.M.	1 19	3 38	9 10	2 19	11 53	14 2	10 34
15 A.M.	1 42	7 18	9 4	5 36			
P.M.	2 5	5 2	10 1	2 57	54	10 9	11 12
16 A.M.	2 28	7 45	9 6	5 17	29	13 9	10 24
P.M.	2 51	5 29	10 3	2 38	1 28	11 1	11 0
17 A.M.	3 13	8 6	9 5	4 53	45	13 5	9 54
F.M.	3 35	6 19	10 6	2 44	2 13	11 2	11 0
18 A.M.	3 57	8 30	9 6	4 33	1 11	13 0	9 36
P.M.	4 19	7 59	10 7	3 40	2 54	11 5	10 57
19 A.M.	4 41	9 10	9 5	4 29	1 57	12 5	9 38
P.M.	5 2	9 6	10 10	4 4	3 28	11 9	10 47
20 A.M.	5 23	9 59	9 6	4 36	2 40	11 11	9 38
P.M.	5 45	10 50	10 8	5 5	4 11	12 1	10 48
21 A.M.	6 7	10 4	9 2	3 57	2 45	11 1	9 0
P.M.	....	....	....	....	5 27	12 5	11 20
22 A.M.	6 29	1 22	10 4	6 53	3 28	10 6	8 59
P.M.	6 53	10 33	8 11	3 40	6 29	12 11	11 36
23 A.M.	7 17	2 26	10 1	7 9	4 32	10 2	9 15
P.M.	7 41	10 50	9 1	3 9	7 8	13 7	11 27
24 A.M.	8 6	3 27	9 8	7 21			
P.M.	8 32	11 23	9 1	2 51	8 1	14 2	
25 A.M.	8 58	4 17	9 6	7 19			
Oct. 6 A.M.							
P.M.	9 37	....	....	....	9 12	14 3	11 35
7 A.M.	9 59	3 12	12 1	5 13	9 44	14 8	11 45
P.M.	10 21	4 24	11 10	6 3	10 1	13 9	11 40
8 A.M.	10 43	3 39	11 10	4 56	10 9	14 10	11 26
P.M.	11 5	5 11	11 7	6 6	10 31	13 5	11 26
9 A.M.	11 27	3 58	11 7	4 31	10 38	15 3	11 11
P.M.	11 49	5 31	11 5	5 42	11 2	13 2	11 13
10 A.M.	13	4 39	11 6	4 26	11 3	15 3	10 50
P.M.	37	6 21	10 11	5 44	11 47	12 4	11 10
11 A.M.	1 1	4 50	11 1	3 49	11 59	15 6	10 58
P.M.	1 26	7 0	11 2	5 34			
12 A.M.	1 51	5 4	11 2	3 13	4	12 5	10 38
P.M.	2 17	8 21	11 5	6 4	1 0	15 7	11 9
13 A.M.	2 43	5 19	11 2	2 36	12 0	12 3	9 43
P.M.	3 10	8 56	11 6	5 46	1 14	15 7	10 31
14 A.M.	3 38	5 59	11 5	2 21	1 53	12 5	10 43
P.M.	4 6	9 19	12 0	5 13	1 42	16 0	10 4
15 A.M.	4 34	6 34	11 10	2 0	2 50	12 7	10 44
P.M.	5 2	11 9	12 1	6 7	2 37	15 10	10 3
16 A.M.	5 30	8 16	12 2	2 46	3 25	12 10	10 23
P.M.	5 59	11 32	11 9	5 33	3 47	15 4	10 17
17 A.M	6 27	9 9	12 6	2 42	6 0	12 9	12 1
P.M.	....	....	....	....	4 55	14 11	10 28
18 A.M.	6 54	28	12 1	5 34	6 58	13 5	12 4
P.M.	7 22	11 38	12 7	4 16	6 9	14 8	10 47
19 A.M.	7 49	54	12 0	5 5	8 0	14 2	12 11
P.M.	8 16	1 38	12 4	5 22	7 23	14 3	11 7
20 A.M.	8 43	1 22	11 9	4 39	8 6	14 6	11 23
P.M.	9 10	2 37	11 11	5 27	8 2	13 9	10 52

Petropaulofsk. (Continued.)

	Moon's Transit.	High Water. Times.	High Water. Heights.	Interval.	Low Water. Times.	Low Water. Heights.	Interval.
1828.	h m	h m	ft. in.	h m	h m	ft. in.	h m
Oct. 21 A.M.	9 36	2 7	11 7	4 31	8 59	15 1	11 23
P.M.	10 2	4 12	11 1	6 10	9 13	12 5	11 11
22 A.M.	10 28	2 16	10 4	3 48	10 0	14 6	11 32
P.M.	10 54	4 36	10 5	5 42	10 13	12 4	11 19
23 A.M.	11 21	3 25	10 3	4 4	10 25	14 11	11 4
P.M.	11 47	5 33	10 1	5 46	11 4	11 9	11 17
24 A.M.	13	4 3	10 3	3 50	11 25	15 5	11 12
P.M.	39	6 35	10 2	5 56	11 35	11 10	10 56
25 A.M.	1 6	4 31	10 3	3 25	11 48	15 3	10 42
P.M.	1 32	7 9	10 2	5 37			
26 A.M.	1 59	5 0	10 8	3 1	55	11 9	11 32
P.M.	2 26	7 48	10 6	5 22	34	15 5	10 35
27 A.M.	2 52	5 17	10 10	2 25	1 42	11 9	11 16
P.M.	3 17	8 50	10 10	5 33	1 19	15 3	10 27
28 A.M.	3 42	6 49	10 11	3 7	2 30	11 11	11 13
P.M.	4 7	9 9	10 4	5 2	1 55	14 1	10 13
29 A.M.	4 31	6 37	11 7	3 6	3 3	12 1	10 56
P.M.	4 55	10 11	10 11	5 16	2 31	14 5	10 0
30 A.M.	5 18	8 6	11 7	2 48	3 44	12 2	10 49
P.M.	5 41	10 42	11 0	5 1	3 39	13 10	10 21
31 A.M.	6 4	9 25	12 0	3 21	5 49	12 5	12 8
P.M.	6 26	11 45	11 3	5 19	4 27	13 8	10 23
Nov. 1 A.M.	6 48	10 34	12 7	3 46	7 41	13 5	13 15
P.M.	....	....	....	....	5 44	13 9	10 56
2 A.M.	7 10	28	11 9	5 18	7 26	13 11	12 16
P.M.	7 31	1 29	12 8	5 58	6 14	13 6	10 43
3 A.M.	7 53	39	11 6	4 46			
P.M.	8 15	2 4	11 2	5 49	7 52	12 0	11 37
4 A.M.	8 37	1 36	10 3	4 59	8 11	13 6	11 34
P.M.	8 59	3 43	10 11	6 44	8 0	12 2	11 1
5 A.M.	9 21	1 39	11 1	4 18	9 35	14 10	12 14
P.M.	9 43	3 53	11 6	6 10	8 55	12 8	11 12
6 A.M.	10 6	2 17	11 4	4 11	9 36	15 2	11 30
P.M.	10 29	....	....	....	10 32	12 5	12 3
7 A.M.	....	2 44	11 5				

Port De Lloyd.

Lat. 27° 5′ N. Long. 142° 54′ E.

	Moon's Transit.	High Water.		Interval.	Low Water.		Interval.
		Times.	Heights.		Times.	Heights.	
1828.	h m	h m	ft. in.	h m	h m	ft. in.	h m
May 4 A.M.	3 29	11 23	7 2	7 54	4 43	4 5	1 14
P.M.	3 59	10 34	6 8	6 34	5 49	5 11	1 50
5 A.M.	4 28	12 53	7 2	8 25	5 35	4 7	1 7
P.M.	4 56	11 46	6 8	6 50	7 14	5 10	2 18
6 A.M.	....	....	....	....	7 2	5 0	1 38
P.M.	5 24	2 9	7 1	8 45	8 14	5 7	2 23
7 A.M.	5 51	1 53	6 6	8 2	8 8	5 0	1 50
P.M.	6 18	3 20	7 2	9 2	9 35	5 2	2 51
8 A.M.	6 44	3 7	6 9	8 23	9 30	5 1	2 20
P.M.	7 10	3 53	7 1	8 43	10 22	4 8	2 46
9 A.M.	7 36	4 27	6 10	8 51	10 31	5 2	2 30
P.M.	8 1	4 24	7 1	8 23	10 55	4 6	2 29
10 A.M.	8 26	5 17	7 0	8 51	11 28	5 2	2 38
P.M.	8 50	4 58	7 2	8 8	11 37	4 3	2 22
11 A.M.	9 15	5 56	7 4	8 41	11 36	5 4	1 56
P.M.	9 40	5 19	7 5	7 39			
12 A.M.	10 5	6 48	7 5	8 43	15	4 1	2 10
P.M.	10 29	6 6	7 4	7 37	25	5 6	1 56
13 A.M.	10 54	7 38	7 4	8 44	49	4 0	1 55
P.M.	11 19	6 24	7 2	7 5	49	5 6	1 30

Bay of St. Croix.

	Moon's Transit.	High Water Times.	High Water Heights.	Interval.	Low Water Times.	Low Water Heights.	Interval.
1828.							
Sept. 9 A.M.		9 30	9 6		4 30	4 11	
P.M.		10 5	9 1		4 15	4 7	
10 A.M.		10 35	10 1		4 45	4 4	
P.M.		10 30	10 6		5 0	4 9	
11 A.M.		10 35	10 4		4 45	4 7	
P.M.		11 10	10 6		5 15	4 7	
12 A.M.		11 10	10 5		5 30	4 7	
P.M.		11 40	10 11		6 30	4 5	
13 A.M.		11 35	10 1		6 0	4 6	
P.M.		....	....		7 0	4 6	
14 A.M.		15	11 0		7 0	4 4	
P.M.		7	9 7		7 15	4 2	
15 A.M.		1 10	10 10		7 0	4 6	
P.M.		50	9 10		7 30	4 7	
16 A.M.		1 37	11 5				

Port De la Coquille.

Lat. 5° 21′ N. Long. 163° 5′ E.

	Moon's Transit.	High Water.		Interval.	Low Water.		Interval.
		Times.	Heights.		Times.	Heights.	
1827.	h m	h m	ft. in.	h m	h m	ft. in.	h m
Dec. 12 A.M.		11 30	7 3		5 29	6 2	
P.M.		....	....		6 25	5 6	
13 A.M.		20	8 2		7 0	5 9	
P.M.		38	7 6		6 26	5 3	
14 A.M.		9	8 6				
P.M.		1 27	7 7		7 18	4 8	
15 A.M.		1 38	9 4		8 29	4 7	
P.M.		1 49	9 0		7 55	4 9	
16 A.M.		2 40	9 9		9 16	4 4	
P.M.		2 27	8 4		8 29	4 9	
17 A.M.		2 48	10 2		9 35	4 3	
P.M.		3 36	8 3		9 16	4 7	
18 A.M.		3 33	9 3		9 57	4 1	
P.M.		3 35	8 4		10 14	4 5	
19 A.M.		4 11	10 1		11 7	3 7	
P.M.		....	....		10 32	4 5	
20 A.M.		4 57	9 3				
P.M.							
21 A.M.		5 26	9 10				
P.M.		6 9	8 6		18	5 5	
22 A.M.		6 23	9 4		16	6 0	
P.M.		8 14	8 2		1 1	5 1	
23 A.M.		7 3	8 9		31	6 8	
P.M.		9 23	8 2		1 38	6 1	
24 A.M.		8 30	8 3		3 30	6 11	
P.M.		10 35	8 3		4 13	6 7	
25 A.M.		10 39	7 11		3 43	7 1	
P.M.		....	....		4 11	6 5	
26 A.M.		12 0	8 8		7 35	6 6	
P.M.		47	7 11		6 22	6 7	
27 A.M.		57	8 10		8 32	6 5	
P.M.		1 28	7 10		6 43	6 4	
28 A.M.		1 25	8 11		7 37	6 4	
P.M.		1 32	7 10		7 35	6 3	
29 A.M.		2 33	9 3		7 57	5 11	
P.M.		2 46	8 1		8 12	5 10	
30 A.M.		2 37	9 6		9 3	5 5	
P.M.		3 16	8 1		8 48	5 10	
31 A.M.		3 7	9 9				
P.M.							

Sitkhœ, Norfolk Sound, N.W. coast of America.

Lat. 57° 2′ N. Long. 135° 18′ W.

	Moon's Transit.	High Water.		Interval.	Low Water.		Interval.
		Times.	Heights.		Times.	Heights.	
1827.	h m	h m	ft. in.	h m	h m	ft. in.	h m
July 1 A.M.							
P.M.	5 20	5 44	13 0	12 22	11 53	9 1	6 10
2 A.M.	5 43	6 22	15 4	12 39			
P.M.	6 6	7 11	12 11	13 5			
3 A.M.	6 32	7 25	15 10	12 53	58	8 10	6 26
P.M.	6 59	8 47	13 3	13 48			
4 A.M.	7 26	8 17	16 8	12 51	1 55	9 2	6 29
P.M.	7 53	9 57	13 8	14 4	3 17	6 3	7 24
5 A.M.	8 21	9 19	16 9	12 58	3 5	9 5	6 45
P.M.	8 51	10 50	14 4	13 59			
6 A.M.	9 21	....	....	....	4 10	9 5	6 49
P.M.	9 51	11 29	15 2	13 38			
7 A.M.	10 22	11 34	18 3	13 12	5 10	9 2	6 48
P.M.	....	....	....	....	6 1	4 0	7 8
8 A.M.	10 52	42	16 8	13 49	5 52	8 7	6 27
P.M.	11 25	....	....	....	6 46	3 3	6 49
9 A.M.	11 57	1 22	15 8	13 25	6 40	7 8	6 14
P.M.	28	42	17 6	12 14	7 40	3 2	6 42
10 A.M.	58	2 10	16 2	13 12	7 34	7 8	6 7
P.M.	1 27	1 42	17 4	12 12	8 14	3 8	6 19
11 A.M.	1 55	2 48	16 2	12 53	8 34	7 4	6 12
P.M.	2 22	2 28	16 5	12 6	8 53	4 7	6 5
12 A.M.	2 48	3 35	16 3	12 47	9 24	7 6	6 10
P.M.	3 14	3 13	15 6	11 59	9 39	5 7	6 0
13 A.M.	3 39	4 9	16 1	12 39	10 16	7 7	6 13
P.M.	4 3	4 10	14 6	12 7	10 22	6 9	5 55
14 A.M.	4 27	4 52	15 7	12 25	11 22	7 7	6 32
P.M.	4 50	5 20	13 4	12 30	11 12	7 8	5 58
15 A.M.	5 14	5 24	15 1	12 10	11 55	7 10	6 18
P.M.	5 37	6 14	12 8	12 37			
16 A.M.	6 0	6 37	15 2	12 37	1 3	8 11	7 3
P.M.	6 23	7 58	12 8	13 35	1 29	7 10	7 6
17 A.M.	6 43	7 44	15 4	13 1	1 27	9 11	6 44
P.M.	7 10	9 8	13 1	13 58	2 57	7 9	6 48
18 A.M.	7 33	8 19	15 6	12 46	2 2	10 7	6 29
P.M.	7 57	10 6	13 4	14 9	2 42	8 0	6 45
19 A.M.	8 20	9 6	15 6	12 46	3 34	10 6	7 14
P.M.	8 44	11 13	13 9	14 29	3 47	8 0	7 3
20 A.M.	9 7	10 17	15 10	13 10	4 22	10 4	7 15
P.M.	9 31	11 33	14 1	14 2	5 20	6 3	7 49
21 A.M.	9 55	11 31	16 2	13 36	5 27	9 10	7 32
P.M.	....	....	....	....	5 18	7 10	6 59
22 A.M.	10 19	22	14 9	14 3	5 39	10 2	6 56
P.M.	10 43	11 39	16 8	12 56	6 22	6 0	7 15
23 A.M.	11 7	40	15 0	13 33	6 12	9 7	6 41
P.M.	11 31	14	16 8	12 43	6 53	5 10	6 59
24 A.M.	11 54	57	15 2	13 3	7 19	9 2	7 2
P.M.	17	1 30	14 9	13 13			
25 A.M.	40	1 46	15 2	13 6	7 55	8 9	6 52
P.M.	1 3	....	....	....	8 4	5 11	6 38
26 A.M.	1 26	2 33	15 11	13 7	8 9	8 11	6 20
P.M.	1 49	....	....	....	8 38	5 10	6 27
27 A.M.	2 11	3 49	15 7	13 38			
P.M.	2 33	3 29	14 11	12 56	9 59	7 1	7 3
28 A.M.	2 56	3 30	15 7	12 34	9 31	7 11	6 12
P.M.	3 19	3 29	14 6	12 10			